Analysis and Issues in the Space Station Redesign

by

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ABSTRACT

By 1992, the international space station, dubbed Space Station Freedom, had been designed in detail but had not yet been built to any significant extent. However, the program was costing over $2 billion per year. In March, 1993, President Clinton asked NASA to redesign the space station to make it cheaper. A three-month redesign effort was implemented, and a report submitted that detailed three cheaper designs. However, soon after this report was submitted, the Administration invited Russia to join the international space station effort; the addition to the team had significant impact on the space station design, cost, schedule, and purpose. The turmoil in the space station program caused by these two events, the redesign and the addition of Russian participation, raised questions, both political and technical, about the goals of the space station program.

This thesis explores some of the issues raised during this time period. The justification of the space station, the reasons for the redesign, the results of the redesign, the important management changes in the space station program, and the reasons for and the effects of the addition of the Russians to the program are discussed. The most important result of the redesign was the management restructuring of the space station program. The technical changes proposed by the redesign were not very extensive, and were immediately obviated by the decision to add the Russians to the program. The addition of the Russians was a purely political decision that had serious technical consequences to the space station program. However, it provided a political justification for the space station in addition to the technical justifications. The problem of justifying the space station and other large space programs is explored.

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Dedicated to my mother

Audren L. Fricks

and to the memory of my father

Donald C. Fricks

for their love and support.

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Introduction

NASA has a great deal of difficulty in justifying the space program. Part of the problem lies in a lack of communication between two groups of people: the Believers and the Non-believers. The Non-believers see the space program as interesting and impressive, but with far too high a price tag for the return. The Believers see the space program as intrinsically and even obviously vital to the future of mankind. In fact, this importance is so clear to the Believers that they are often puzzled and tongue-tied when asked to explain the reasons why space exploration is important. The question might as well be "Why do you breathe?" The answer is obvious. Space is an unknown. To the Believers, the urge to explore and define it is very strong. Why did Robert Peary go to the North Pole? Why did Sir Edmund Hillary climb Mount Everest? Why did Charles Lindbergh fly across the Atlantic? Because it was there; to prove it could be done; because no one had done it yet: all these are reasons that apply to space exploration as well.

The largest objection the Non-believers have to the space program is that of cost. In these difficult economic times, the question can no longer simply be: "Is it worth doing?"; it now must be: "Is it worth doing at this price?" Any answer to this question must necessarily be very subjective. There is no formula that can be used to calculate the line between "worth the price" and "too expensive." How can the value of exploration and discovery be distilled down to a single quantity, given in dollars and cents? Believers exclaim that the expansion of knowledge has unlimited intrinsic value. Non-believers quickly disclaim: the value is there, certainly, but it is not unlimited. If space exploration could be pursued for only a minor investment, there would be no objection. However, the cost of this exploration is very high, and therein lies the problem.

Space exploration can be compared to medical research. They both represent a frontier of knowledge that dedicated professionals strive to push back every day. Non-believers quickly point out that the comparison is not valid: medical research is intrinsically necessary in the saving of human lives. The Believer claims that space exploration is intrinsically necessary in the saving of the human soul. In humans the urge is very strong to explore, to discover, to seek, to know. When this urge is no longer felt or no longer indulged, the human soul will die. The difference between humans and robots will have disappeared but for the minor differences in component parts. Another objection to this analogy is the difference in cost of the two programs. In FY1991, the federal government spent $5 billion on basic research in health-related fields.[1] In contrast, NASA's budget for FY1993 was $15 billion, and the space station alone was $2.25 billion. Space exploration is an expensive endeavor. However, the money spent is an investment in the future of mankind.

Inside this large debate there is a smaller debate: manned vs. unmanned exploration. To many, it is seen as a compromise: unmanned exploration provides most of the benefits of space exploration with a substantial savings over manned exploration. Believers, however, see it as a very poor substitute. Unmanned exploration is less of a challenge, and less risk is involved. The greater the challenge, the more determined the attack at the boundaries of the known will be. Unmanned exploration is the trickle of water that slowly wears down the rock; manned exploration, the waterfall that pounds the rock mercilessly. Exploring the unknown is a very uncertain business; only man has the imagination, ingenuity, and creativity to respond to unforeseen situations. For robotic missions, unforeseen circumstances often mean the end of the mission. Manned missions, however, can adapt and change to the environment, providing a greater margin for success.

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[1]National Science Board, *Science and Engineering Indicators 1991*, 1992.

In the middle of both the space exploration debate and the manned vs. unmanned debate lies the space station. To Believers, the space station is the obvious next step in the manned space program. It represents a commitment to inhabit space permanently; not just to be satisfied with brief visitations. To Non-believers, it is an example of wasted money and an inappropriate space policy. "Why does man need to inhabit space permanently?" they ask. Believers may explain, "Because it's there and it hasn't been done before," but this reason is not good enough. This problem of justification has led to an uneasy alliance between space explorers and politicians. Space programs have been most strongly supported when they fulfill a political purpose as well as the obvious scientific purpose. Apollo was widely supported because it was used to prove U.S. scientific and military superiority to the world. The politicians provided money and an important justification, while NASA provided the vision and the hard work. The Believers in space exploration have mixed feelings about this alliance; they appreciate the support (both monetary and popular), but they are wary of the implications. If a space program needs a political justification, this implies that the vision and hard work are not enough. Future missions are jeopardized because political justifications cannot be found for them. Apollo set a precedent that has haunted the space program: a successful mission needs political justification in order to get support. Scientific justification is not enough.

Where does this leave the space station and the space program today? The space station was almost canceled at the beginning of the Clinton Administration. Expenses kept increasing while justification dwindled. At almost the last minute, the miracle of politics struck again. An alliance was formed with the Russians to complete a joint space station. The strong Soviet space program, after the breakup of the Soviet Union, was facing dire economic circumstances. In addition, the new Russian Republic had an unstable political environment. The U.S. administration

began to fear that to combat these problems, either the Russian government or the Russian space program would be forced to sell their technology in order to survive. To stop the potential spread of military technology, the U.S. stepped in with an offer to help fund a joint space station. Almost instantly, the space station became an important program. While not as popularly supported as Apollo, it no longer faced imminent cancellation. The double-edged sword of the political justification saved the space program again.

Historical Context of the Space Station

In 1984 President Reagan announced a commitment by the United States to build and launch a permanently manned space station by the end of a decade. He was trying to emulate President Kennedy's 1961 announcement of a U.S. commitment to send men to the moon. However, the space station program has not met with the support and the success of the Apollo program. While the Apollo program benefited from consistent funding and broad-based popular, congressional, and administrative support, the space station program has suffered from budget cuts and general disinterest. Both programs were very expensive, and the scientific communities at large did not believe that the scientific merits of the programs justified the costs. However, the money for programs this large and expensive comes directly from the government, where spending is controlled by politicians. Therefore, the reasons that the U.S. pursued these two large space programs were primarily political in nature. The reasons for the differences between these two programs can be found by looking at the differences in the political atmospheres at the times of these two decisions.

Apollo

When President Kennedy made the Apollo decision in 1961, the United States had just received a shock to its national pride.[2] The flight of Yuri Gagarin in April, 1961, just months after Kennedy had taken office, made the U.S. face the incredible possibility that the Communist bloc countries were more technologically advanced. The overwhelming opinion at the time was that the capitalist countries, led by the U.S., were in a vitally important competition with the Communist countries, led by the Soviet Union. This competition was for the alliance of the unaffiliated third-world countries. Technological achievement was often equated with military and ideological

[2]A further discussion of the events surrounding Kennedy's decision and of the national prestige policy argument is found in *The Decision to Go to the Moon*, by John M. Logsdon, MIT Press, 1970.

superiority. The Gagarin flight sent a message to the world stating that Communism was superior to capitalism because it first put a man in Earth orbit. President Kennedy felt the need to restore the national prestige of the United States, both internationally and internally. He turned to the National Aeronautics and Space Administration (NASA) and asked with what spectacular achievement could the United States defeat the Soviets.

NASA replied that there were several options. There was no chance that the U.S. could beat the Soviets in orbiting a manned space laboratory (i.e., a space station), however, the Soviets were not ahead of the U.S. in developing the resources necessary to go to the moon.[3] Neither the Soviet Union nor the U.S. had the large launch vehicles necessary for a trip to the moon, but the U.S. was already developing both the Saturn and the Nova rockets, both large enough to use for a translunar launch. The question then became what the U.S. could accomplish at the moon. Some of the suggestions were to send an unmanned probe around the moon, land an unmanned probe on the surface of the moon and return with rock and soil samples, send a manned probe around the moon, and to land a man on the moon and return him to earth. On May 10, 1961, President Kennedy made the decision that the United States should put a man on the moon.

NASA had been trying to get a major space initiative approved for several years prior to 1961. The possible programs included a space shuttle, a space station, a manned trip around the moon, a manned landing on the moon, and unmanned probes to the planets. Opponents of the space program felt that these initiatives were too expensive and did not have enough scientific merit to justify the cost. However, President Kennedy saw these objections as insufficient to counter the demands of national prestige. He was ready to support any program that had a good chance of

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[3]Logsdon, *The Decision to Go to the Moon*, pg. 113.

beating the Soviets. Furthermore, the U.S. had the money to pay for it. Kennedy's Budget Director, David Bell, was unconvinced that the venture was worth the huge price tag. However, he knew that the money to pay for it was available if necessary.[4] After weighing the cost of the program versus the national prestige, Kennedy made his decision. On May 25, 1961, Kennedy announced: "I believe that this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

In the spirit of competition with the Soviets, Congress supported this goal as well. When NASA Administrator James Webb went before Congress to ask for the funding for Project Apollo, he was given what he asked for with very little argument. At the time, Webb was not sure exactly how much money to ask for. The cost figures that NASA was looking at were in the $10 billion range. However, Webb decided to ask for $20 billion. At the meeting, he decided to double to figure again. When asked what the cost of going to the moon would be, Webb replied that he did not know for sure but that it would cost at least $20 billion and possibly as much as $40 billion. For some reason, the $20 billion figure was the one that was remembered, and was, in fact, very close to the $24 billion that Apollo actually cost.[5] Over the ten-year span of Project Apollo, NASA did not have to compromise with Congress to get the funding it requested. Popular support of the Apollo Mission was also very strong. The American people, in the spirit of the Cold War, were eager to support a highly visible technical program that enhanced national prestige.

The Space Station

The differences between the Apollo program and the space station program are clear when viewed from a political point of view. By 1983 the Cold War had faded

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[4]Logsdon, *The Decision to Go to the Moon*, pg. 155.
[5]Shea, Joseph. Conversations with the author, 1992.

from people's minds, and by 1989 it was over completely. The National Debt had risen to an alarming height. The space shuttle, while successful, was no longer headline news. National attention had shifted away from the space program. As the space shuttle development program was nearing completion in 1982, NASA needed a new program to capture national attention, focus their efforts, and to fill the funding gap that the completed development program left in NASA's budget. At the June, 1981, confirmation hearings of Jim Beggs for NASA Administrator, Beggs told the Senate confirmation committee that he believed the space station was the next logical step in space for NASA.[6] He pushed for the space station to be included in President Reagan's new space policy. NASA administrators, hoping for an Apollo-type commitment to the space station once the space shuttle was fully operational in 1982, were disappointed.[7] The urgency behind the Apollo decision no longer existed. NASA's primary argument for the space station was that it was "the next logical step in space." However, not everyone agreed with this statement, especially since this "next logical step" came with a multi-billion dollar price tag.[8]

For two years Jim Beggs and a small space station task force tried to sell the idea of a space station to the administration and to Congress. They used a "mission" approach to try to keep opposition to the space station down. Instead of showing pictures of what a space station looked like or a design for space station hardware, they explained what missions a space station would fulfill. By not giving the opposition any concrete features to object to, they hoped to emphasize the features of a space station that people found exciting, interesting, and useful.[9] In August, 1982, John Hodge of the Space Station Task Force went before the White House Office of

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[6]McCurdy, *The Space Station Decision*, pg. 38.
[7]McCurdy, *The Space Station Decision*, pg. 61.
[8]A general discussion of the history of the space station decision is given in *The Space Station Decision* by Howard E. McCurdy.
[9]McCurdy, *The Space Station Decision*, pg. 97.

Management and Budget (OMB) to explain NASA's budget request for fiscal year 1984. Included in the budget was $63 million for space station research. In a total budget request of $7.3 billion, this seems like a very small slice. However, NASA was hoping to get the space station approved incrementally. By asking for a little money in 1984, and then a little more in 1985, eventually NASA hoped that they could justify large expenditures on the space station by pointing out the work that had already been accomplished.[10] However, the OMB had other plans. Since they had no directive from the President supporting a space station, they refused to give NASA any money for the space station. In a compromise, NASA was given only $14 million for space station research in FY 1984.[11]

NASA was hampered in its attempts to find support for the space station by opposition from the Department of Defense (DoD).[12] DoD Secretary Casper Weinberger was very concerned that if NASA began developing a space station, the space shuttle program would suffer. Since the DoD had completely committed itself to the space shuttle for all access to space, this was a very important issue. President Reagan supported the Strategic Defense Initiative, which would move some of the defensive capability of the U.S. into space. Hence, the defense community saw the space shuttle as integral to their needs, while the space station was considered unnecessary for any defense purposes.

Faced with the opposition of the national security community, NASA decided to emphasize the civil uses for a space station. In an April, 1983, briefing to the President, Beggs emphasized leadership in space, technology spin-offs, commercial applications, motivating the country in terms of economic recovery and science and technology advancement, and pointing the way to the future.[13] Possible missions for

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[10]McCurdy, *The Space Station Decision*, pg. 119.
[11]McCurdy, *The Space Station Decision*, pg. 123.
[12]McCurdy, *The Space Station Decision*, pg. 167.
[13]McCurdy, *The Space Station Decision*, pg. 138.

the space station that NASA widely circulated were that it would provide a facility for manufacturing of pharmaceuticals, a means of deploying remote sensing devices for a better understanding of the earth and its resources, a better understanding of how humans function in space, and a permanent base for servicing and repair of satellites and space-based research and development.

When NASA tried to sell the space station in meetings that were dominated by the national security community (i.e., the Department of Defense, the National Security Council, the Central Intelligence Agency), they faced overwhelming opposition. However, they eventually found a forum in which the space station was better received. The Cabinet Council on Commerce and Trade included several representatives from civil departments as well as the national security community. In addition, this forum emphasized the commercial potentials of space that NASA had been trying to introduce. At a meeting of this council on December 1, 1983 , NASA again presented the space station program. For the first time, the number of supporters of the program equaled the number of opponents. NASA brought a five-foot model of the space station to the meeting and explained it to everyone. On December 5, 1983, Beggs went before the President and asked for support for an $8 billion space station with a $150 million budget in the upcoming year. In addition, he wanted a slight increase in NASA's overall funding. David Stockman, head of the OMB, was there to oppose the increase. They reached a compromise of a 1 percent increase in NASA's budget. In addition, the President agreed to support the space station.

President Reagan announced the commitment to building a space station in the 1984 State of the Union Address. The reasons he gave for this decision included technological leadership for the United States, enhancement of the economy, scientific and technical advances, and international cooperation.[14] President Reagan had been a

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[14]McCurdy, *The Space Station Decision*, pg. 190.

supporter of the space program since his early days as a politician in California, where the aerospace industry employs thousands of workers. He wanted to support the space program in a way that his predecessors had not. NASA took advantage of the fact that there was a space enthusiast in the White House. However, instead of presenting several choices, as was done for President Kennedy in 1961, NASA simply presented President Reagan with plans for a space station. If President Reagan was serious in his support for space, he had no other option than to support the space station.

Differences in Justification

The space station has been rationalized as the next logical step in space, a direct descendant of the space shuttle and the Apollo program. However, the justifications for the space station and for the Apollo program are very different. The justification for the Apollo program was technological leadership. In the context of international events at the time, this translated into political leadership as well. Technological leadership was also an important justification of the space station. However, in the context of post-Cold War international relations, political leadership was much more loosely associated with advanced technology. The other important justifications of the space station were space commercialization, international cooperation, and economic stimulus. These reasons were never applied to Apollo.

Space Commercialization

The commercialization of space has advanced significantly since the Apollo era. In the 1960's, space was strictly a government concern. It was so expensive an enterprise that only governments could afford it. By 1983, however, there was a significant unmanned commercial space business. Launch vehicles and communications satellites were two of the most successful commercial ventures into

space. The Space Station Task Force, when compiling the missions that the space station could complete, included some possible commercial applications such as space manufacturing and pharmaceutical development and production. However, these are not high return investments—especially when the laboratory or manufacturing facility has to be staffed by people.

Historically, business concerns have pushed at new frontiers, hoping to become rich by bringing goods from new exotic places and selling them back home. Traders went to the Far East to bring back silk and spices. Explorers ventured into the wilds of the New World to bring back animal hides and beaver pelts for markets in Europe. This will not work in space. As a frontier, space is expensive and difficult to reach. So far, commercially viable products or industries that call for the presence of people in space have not been identified. Some day there will be commercial enterprises in space that include people: mining of the asteroids, for example, or a shuttle service between the earth, orbiting space stations, and perhaps a moon base. However, that time is far in the future. There needs to be a significant manned space infrastructure provided by the governments of the world before serious manned commercial ventures into space will be profitable.

International Cooperation

When President Reagan announced his support of the space station, he invited the allies of the United States to participate. Of the allies, Canada, Japan, and the European Space Agency (ESA) were interested in joining the U.S. to develop a space station. At first the international partners were skeptical. They did not want to be involved in a space station that would have even a partial military mission. However, the disinterest of the Department of Defense gave Beggs the freedom to assure the

partners that the space station would be a purely civil pursuit.[15] Once assured of this, the international partners were willing to participate, but wanted a detailed accounting of who would be responsible for what in terms of expense, hardware, and personnel. In early 1985, the U.S. signed a Memoranda of Understanding with ESA, Canada, and Japan agreeing to conduct joint Phase B (detailed definition and preliminary design) studies with NASA on the space station. In late 1988, the U.S., the member countries of ESA, Canada, and Japan, signed another Memorandum of Understanding committing to jointly design, develop, operate, and utilize a permanently manned space station.

An important issue that was instigated by the international participation was whether or not to rely on the international partners for essential station facilities. There was a prolonged debate about whether the international partners' contributions should be necessary for the operation of the station, or if they should enhance the capability of the core station. This issue had important political, risk, and cost implications. The cost could be kept lower for the U.S. by depending on the partners for some of the essential sub-systems. However, this ran the risk of major setbacks if any of the partners withdrew from the project. On the other hand, if the international partners were delegated a very secondary role in the space station, they might decide not to participate at all. In the end, U.S. conservatism won out. The U.S. decided to build a core space station with all of the essential components, and the international partners would add laboratories and other equipment to enhance the core station. As a result of this, the design was never optimized to take advantage of the integrated contributions of the partners.

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[15]McCurdy, *The Space Station Decision*, pg. 198..

Economic Stimulus

During President Reagan's two terms in office, the U.S. economy steadily declined. One of the things he hoped a space station program would accomplish was to give a needed boost to the economy, and especially to the aerospace industry. Politically, it was very important for him to be seen taking positive steps toward a stronger economy. By starting a large program such as this, he was trying to boost confidence in the economic strength of the country. Space programs were not only perceived as the domain of technologically advanced countries, but also of economically stable countries. Only very wealthy and stable countries could afford a multi-billion dollar investment in space. President Reagan was hoping to boost confidence in the U.S. economy, and to boost the economy itself.

Technological Leadership

It is indisputable that large technical programs of this sort increase the scientific and technical knowledge of our society. However, major factions of the scientific community did not generally believe that the large cost associated with the space station was worth the return.[16] Across the broad range of space science, the space station could serve to advance only a narrow range of disciplines. This range included space life science, space manufacturing, and microgravity research. Research that covered the rest of the spectrum could only be hindered by the presence of people in space. Either the vibrations caused by people moving and working, or the power and facilities required to keep people alive in space, or the overhead caused by the presence of people made the space station unsuitable for research in many areas of space science. As a science laboratory, the space station is not a sound investment.

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[16]McCurdy, *The Space Station Decision*, pg. 80.

The technological leadership of the United States has historically been a national priority. It is a part of the national culture of the United States to advance technologically further and faster than anyone else. The true technological advances instigated by the space station will be simply the knowledge and ability to keep people alive and working in the hostile environment of space. NASA believes that this, in itself, is a worthy goal. If our society is to move into space for the purposes of exploration and commerce, then this know-how is very important. Systematic space exploration will be an extensive, lengthy, and expensive project. As the first step in this program, the space station is a good investment. However, the real issue is whether or how soon human space exploration will be undertaken.

Space Station Freedom

The Space Station Freedom program officially began in 1984 when President Reagan announced the commitment to put a permanently manned station into earth orbit. From 1982 until 1992, roughly $9 billion was spent on space station research and development costs. However, from many points of view not much was accomplished for the $9 billion. There was a finalized SSF design, and most of the major contracts had been awarded. Some of the contractors had built hardware. However, the first element launch date had been pushed back from 1992 until 1996. A design for the Assured Crew Rescue Vehicle, a vital part of the space station program, had not yet been finalized. There was considerable concern over the launch schedule. It was based on a very ambitious plan to launch eight shuttle flights per year. However, the shuttle program had not yet been able to sustain such a busy flight schedule. The estimated cost of the program kept increasing along with the expected length. When President Clinton called for a redesign in 1993, he asked NASA to identify what was causing these schedule and cost increases and how to contain them.

Technical Aspects

The design of SSF changed many times between 1983 and 1992. One of the reasons for this is that NASA kept adding more requirements. NASA wanted the space station to fulfill as many missions as possible in order to build a broad base of support for the space station. As missions were added, requirements were added as well. With each set of new requirements, the space station changed and grew a little. This also increased the cost and length of the space station program, as well as the cost of the space station itself. There was not much of an attempt to design the space station to cost, because a final firm cost had never been stated. The $8 billion figure

given to Congress in 1984 was known to be very low, and NASA did not feel compelled to stick to it.

Managerial Aspects

Many of the problems with SSF were due to a clumsy managerial structure. The management structure had been changed several times, as if NASA kept trying and then rejecting strategies that did not work. The biggest problem was integrating the space station management structure with the NASA management structure. NASA consists of many technical centers, each operating autonomously. Each of these centers also has its own history, its own sense of community, and its own sense of pride. None of them are willing to be subordinate to any other, including NASA Headquarters, which is seen by many inside NASA as just another NASA center. The management structure for the space station reflected this autonomy. Space Station program headquarters was located in Reston, Virginia, outside of the NASA technical centers. Each technical center that was involved in the space station program had its own project manager, who reported to their own center director and to the space station program manager. However, the space station program manager had no authority over the center directors. The lines of authority were very unclear. NASA center directors, who favored this plan, assured that it would work because they and their staffs would keep lines of communication open. "The center directors had bought into a management plan that promised little supervision from above in exchange for cooperation from below."[17] However, NASA superimposed the Reston, Virginia, program office, which had an in-line decision role. Various forms of this structure were tried and discarded over the nine-year SSF program. Without clear lines of authority the program moved forward very slowly.

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[17]McCurdy, *The Space Station Decision*, pg. 209.

Political Aspects

There were several political reasons why the SSF program was not as successful as originally planned. One of the most important of these was inconsistent funding. As Table 1 shows, the funding approved by Congress was far short of the funds needed by NASA to sustain the program on budget and on schedule. The biggest enemy of any large technical program is inconsistent or insufficient funding. Without the requested funding, it is impossible to keep a program on budget and on schedule. The SSF program was hit especially hard by this perennial problem.

Table 1

Space Station Appropriations, Planned and Actual (Millions of Dollars)[18]

Fiscal Year	NASA request (letter 9/8/83)	Approved by Reagan, 1984	Actual Presidential Request	Actual Congressional Appropriation
1985	225	150	150	155.5
1986	270	250	226	205
1987	1,040	1,250	410	410
1988	2,215	1,700	767	425
1989	2,420	2,000	967	900
1990	1,510			
1991	320			

Note: The figures in columns 1 and 2 are stated in 1984 dollars. Those in columns 3 and 4 are stated in current year dollars. The numbers in column 2 are taken from a graph and are therefore approximate.

Another significant political problem with the SSF program was the political opposition and lack of credibility. Many people, both in the general public and in Congress, were not convinced of the importance of the space station. The administration had not come out with any clear reason why there should be a space station. The general and somewhat fuzzy justifications of the enhancement of the U.S. technological base and the "next logical step in space" did not convince them in the

[18]McCurdy, *The Space Station Decision*, pg. 234.

face of the enormous cost of the project. Their skepticism was enhanced by problems in the program such as the cost over runs and the schedule slippage.

The Space Station Redesign

The election of President Bill Clinton in 1992 had a serious impact on the space station. President Clinton was elected on a ticket that endorsed severe spending cuts to reduce to federal deficit. The White House did not want to cancel the space station program because President Clinton had supported it in the campaign, and it was a popular program with widespread, although not overwhelming, support. However, Leon Panetta, director of the White House Office of Management and Budget (OMB), informed Dan Goldin, NASA's administrator, that the U.S. could not afford the current Space Station Freedom program. He asked if a space station costing half as much would be feasible. Goldin assembled a group of expert engineers for a weekend of brainstorming. At the end of the weekend they had three ideas for a scaled down space station that they believed would cost significantly less than the Space Station Freedom baseline design.[19]

Option One was a human-tended base that would be visited by a long-duration orbiter (LDO, i.e., an orbiter modified to stay up to 30 days in orbit). It included a docking adapter, a power module with solar arrays, and a short utility module. The LDO would dock to the station and provide life support and habitation facilities for the astronauts. During their stay, the astronauts could use the station as a base to launch and repair satellites, run experiments on the station, and evaluate experiments that have been running since the last shuttle visit. An advantage to this design is that the space station would be operational (although not permanently manned) after one launch. Also, the presence of a docking adapter would allow the station to evolve over time.

The second idea, labeled Option Two, was a basic permanently-manned station. It did not have a truss structure; the entire station consisted of three modules

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[19]Conversation with Joe Shea, March 1993.

and an Assured Crew Rescue Vehicle (ACRV). One shuttle launch would bring up a long utility module including the solar arrays, heat radiators, station-keeping thrusters, guidance and control systems, docking ports at each end, and laboratory facilities. A second launch would bring up a habitation module which would dock with the utility module. The third launch would add a docking adapter and an ACRV, making the station fully operational. The docking adapter would allow for the docking of the international labs and for further growth in the design.

The third and final idea, Option Three, was a significant departure from the modular approach of Space Station Freedom (SSF) and the other two options. The station would essentially be a can, about 21 feet in diameter and 90 feet long, that could be launched instead of an orbiter with a space shuttle launch configuration. The can would have seven internal floors that would house the experiments and the housekeeping functions of the station. The advantages to this design was that it gave a great deal of internal volume, it could be completely checked out on the ground before launch, and it only required one launch. However, it also required building and qualifying an essentially new launch vehicle.

The Station Redesign Team

Based on these ideas, Panetta gave Goldin and NASA three months to study the designs and cost them out. In March, 1993, Goldin formed a team of engineers, headed by Col. Bryan O'Connor, to redesign the space station. The Station Redesign Team (SRT) immediately came under political pressure from the space station supporters in Congress. The congressmen felt that to scrap all the designs and work of Space Station Freedom was a waste of money. They wanted the Space Station Freedom design to be one of the designs that the SRT considered as it scaled back the

space station program.[20] In the face of this pressure, the SRT modified the three options it was studying. Option A was a simple, modular space station whose origins could be traced back to Option Two of Goldin's expert review. Option B was the Space Station Freedom baseline configuration, scaled back to control the cost. Option C was the single launch core station as described in Option Three of the expert review.

Another team, called the Advisory Committee on the Redesign of the Space Station, was appointed by Vice President Al Gore to evaluate the designs forwarded by the SRT. This panel was led by Dr. Charles Vest, President of the Massachusetts Institute of Technology.[21] The Advisory Committee on the Redesign of the Space Station was group of sixteen experts in the fields of engineering, program management, space science, and cost analysis. Their charter was to evaluate the findings of the SRT on the basis of "technical and scientific capability, accuracy of projected costs, and structure of management and operations,"[22] and to recommend one of the options to the President for budgetary support. The Advisory Committee met three times during the three month redesign. In addition, subcommittees were formed that met regularly with the SRT. Their report and recommendations were given to the President on June 10, 1993.

The SRT was a group of about 45 engineers from NASA and 10 representatives of the international partners. The team was based in Crystal City, Virginia, but engineering support was provided by many different people in the various NASA research centers. The redesign team was charged with coming up with three new designs that supported long duration microgravity scientific research, achieved initial operational capability by 1997, maintained the international

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[20]Lawler, Andrew. "Politics Pose Challenge for Station Redesign," *Space News*. March 22-28, 1993. pg. 3.

[21]Most of the information in the following sections come from attendance at the public meetings of the Advisory Committee on the Redesign of the Space Station, April-June, 1993.

[22]Advisory Committee on the Redesign of the Space Station, *Final Report to the President*, pg. 1.

commitments, had lower operations costs, had reduced extra-vehicular activity (EVA) and on-orbit check-out, simplified the management structure, provided adequate budget reserves, and had a shorter on-orbit lifetime. In addition, the team had an upper-range budget goal of $9 billion. The SRT came up with three options (labeled A, B, and C) loosely based on Options One, Two, and Three described above.

Option A

Option A was formed with the injunction that the engineers look to other programs (such as the space shuttle, the current Space Station Freedom, Space Lab, and Bus-1) for systems that could be incorporated into the space station design. By using these "off-the-shelf" components, cost and development time could be kept to a minimum. The result looked a great deal like a scaled-down Space Station Freedom (SSF). Two different options, labeled Option A-1 and Option A-2 were included under the heading of Option A. Option A-1 used Bus-1, a military satellite bus provided by Lockheed, to provide station keeping, propulsion, and guidance, navigation, and control (GNC) capabilities. Option A-2 used standard or scaled-down SSF components for these functions. A truss supported the structure, and SSF solar panels were added for power. Many of the internal systems were simplified, including a more modest Data Management System. A combined American Lab/Node module and the International Lab modules completed the station.

There are four different configurations, or stopping points, in the deployment of Option A. The first step is the Power Station, and consists of a small truss, solar panels, radiators, Bus-1 (or equivalent subsystems in the case of Option A-2), and a docking mechanism for the space shuttle. The next step is Human Tended Capability which includes a larger truss, more support hardware, and a laboratory module for conducting experiments. The third step is International Human Tended Capability. In

this step, more solar panels and radiators are added for additional power and the International Laboratories are added. The final step is called Permanent Human Capability, which includes the necessary Assured Crew Rescue Vehicles (ACRVs), habitation module and more laboratory facilities. Option A-2 has better performance, but is slightly more expensive and has greater operational risk than Option A-1.[23] Advantages of Option A include its modular build-up approach, components based on previously developed SSF subsystems, and a good accommodation of the International partners.

Option B

Option B was a scaled-down SSF. All the components came from the SSF program. The scaled-down version had no habitation module, was smaller in scale, had less automation and had less capability in terms of communicating with the ground. This option was the most expensive of the three options, but, in most aspects, it had more capabilities than the other options. It also most closely fulfilled the International Agreements. The design for Option B was very mature because it followed the SSF design. Option B, like Option A, was designed for modular build-up. The four steps of Option A were repeated in Option B, with different hardware, slightly different capabilities, and a different deployment schedule. The primary differences between Option B and SSF were not in the hardware, but in the management of the space station program and in the operation of the space station after it is in orbit. The new management and operations plans, described later in this paper, were developed by the SRT for incorporation into all of the Options. SRT studies showed that these simplified management and operations plans were largely responsible for the reduced cost of the space station.[24]

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[23]Advisory Committee on the Redesign of the Space Station, *Final Report to the President*, pg. 26.
[24]Advisory Committee on the Redesign of the Space Station, *Final Report to the President*, pg. 6.

Option C

Option C was a completely new design. It was designed to provide a space station after only a single launch. The station would be built in the shape of a large can, 22 ft. in diameter and over 70 ft. long, with seven internal floors connected by an internal transfer tunnel. This can would be mounted on the space shuttle main engine thrust structure, and launched all at once with the rest of the space shuttle launch system. The internal volume available in this design was much greater than that of the other designs. However, the smaller outer surface area limited the number of solar panels, and therefore the amount of power, available. The can had two docking ports for the space shuttle and seven berthing ports that could house the International Labs and the ACRV's. An important advantage of this option was the capability to do a complete system check-out on the ground prior to launch. However, the International Partners did not feel that this option gave them a significant role in providing vital space station capabilities. Disadvantages to this design included design immaturity, lack of growth capability, an awkward placement of the solar panels that negatively affected the performance of the space station, and the requirement of designing and qualifying an essentially new launch configuration.

International Partners

One of the major stumbling-blocks to the redesign process was the official agreements with the international partners. The Memoranda of Understanding (MOUs) that the U.S. and ESA, Japan, and Canada had signed were explicit in describing the joint space station. The technical details were not included; however, several important features such as the amount of power the U.S. core station would provide each international partner was included. During the redesign, the international partners were very reluctant to compromise on the letter of the agreement as stated in

the MOUs. This constrained the size of the space station. Despite the need to scale back to save costs, the U.S. was obliged to provide the Japanese Experiment Module and the ESA laboratory module with 75 kW of power. This forced NASA to keep the space station large enough to produce this much power, despite the need for drastic cuts in station costs.

In particular, the international partners opposed Option C. Because of the very large internal volume of this option, NASA's initial plan was to allocate a floor of the can each to Japan and ESA for their experiment and laboratory space. However, Japan and ESA felt that the lack of a separate module would adversely affect the support of the joint space station in their home countries. They felt they needed a visible piece of hardware on which they could plant their flag in order to get the support and funding needed to complete the project. When accommodations were made on Option C for the separate international laboratories, the partners were still against the option. Their modules added little to the station in terms of capability, and they could not justify the cost of building large separate laboratories that were, essentially, extraneous. In effect, the international partners eliminated Option C from serious consideration. This is an example of how non-technical issues played a very important role in the space station redesign.

Results of the Redesign

The final cost and schedule estimates for the three Options as well as the SSF baseline are shown in Table 2. None of the Options met the $9 billion target set by the OMB.

Table 2

Cost and Schedule of the Three Redesign Options

	Cost (in billions)	Date
Space Station Freedom	$25.1	March 2001
Option A	$16.5	October 2000
Option B	$19.3	December 2001
Option C	$15.1	January 2001

The final decision between the options was made by the White House based on the report of the Advisory Committee on the Space Station Redesign. The White House did not choose a single option; instead, they chose a configuration that was half-way between Options A and B. Essentially, they chose what was characterized as an enhanced version of Option A. From the White House point of view, Option C did not sufficiently accommodate the International Partners, Option B was too expensive, but Option A did not support enough science. However, since Option A and Option B are very close in design, the de facto decision was for Option B. The White House did not feel comfortable explicitly stating that they supported the most expensive of the options, but that is, in fact, what happened. The final design chosen was a slightly simplified version of Space Station Freedom.

The ostensible reason behind the redesign was to make the space station less expensive. It did not accomplished this goal The design of the space station did not really change very much. A few subsystems and a few modules were altered but the shape of the space station remained the same. In my opinion, the reason for this is that the redesign did not sufficiently challenge the requirements for the space station. Although charged with examining the requirements, the SRT ended up using the same set of requirements that drove the SSF design to define the new design. The source of

these requirements was the list of missions that John Hodge used to sell the space station in 1983. In order to justify the space station and build a strong constituency, NASA developed a list of missions that the space station could fulfill. Each of these missions added requirements to the space station design. Many of these missions were not weighed for their importance or relevance, but simply added to the mission list to give credence to the space station argument.

During the redesign, the SRT did not challenge these missions and their related requirements. Instead they kept the old requirements and ended up with essentially the same design. There could be several reasons for this. First, the redesign was constrained for time. Perhaps the SRT simply did not feel it had enough time to seriously study all the requirements. Also, there might have been a lack of inclination to challenge the requirements. After all, each eliminated requirement meant diminished capability and a smaller space station constituency. NASA had to balance between losing administration support if the cost could not be controlled, and losing congressional support if the capability was diminished.

However, this does not mean that the redesign was useless. On the contrary, it accomplished several very important things not normally related to systems engineering. The most important program changes that came about due to the redesign were the reorganization of the space station management and the new operations plan for the space station. In fact, a large portion of the cost savings was due to these organizational changes. The management of the space station was very awkward and did not have clear lines of authority or responsibility. The lack of a prime contractor and the presence of space station managers in each NASA center confused many issues. The space station managers in each center reported not only to the space station main office but also to their own center director. The redesign made

it imperative that the management structure be pared down and simplified to cut costs. Also, the operations plan was challenged and streamlined by the SRT.

Most importantly, the redesign gave the Clinton administration an excuse to support the space station. The ten-year-old project had already cost the country $9 billion with very little to show for it. In order for the Clinton administration to keep their credibility as deficit reducers and yet still support the space station, some sort of change was needed. It is interesting to note that despite the fact that the redesign did not meet the cost goal, it was not canceled. Panetta, Clinton's budget director, told Goldin at the beginning of the redesign that if the cost goals were not met, the administration would not support the space station. The station redesign provided the administration with a reason to keep the space station by putting it in a new and slightly less expensive package. This new package was a political boon as well, because the new space station could be seen as a Clinton program. The space station program had been initiated under Reagan and continued under Bush. With an altered design (at least nominally) and a new name, it became a Clinton program.

Management

The Station Redesign Team identified the management structure of Space Station Freedom as one of the problems with the space station. Early in the space station program, NASA decided to keep the basic systems engineering, integration, and management of the space station in-house. They did not want to relinquish that level of control over the station to a contractor.[25] The management structure that evolved maximized the participation of the NASA centers at the expense of simplicity. The SRT team in charge of management, led by Walt Brooks, conducted many interviews with people at all levels of space station management, both inside NASA and at the contractors. The overwhelming consensus was that the management structure was unwieldy and was the cause of many of the cost and schedule problems the SRT was trying to fix.

Space Station Freedom Management

The Space Station Freedom program management was divided into three tiers. The first tier was the Associate Administrator for Space Development and Space Station Director located at NASA headquarters in Washington, DC. The second tier was the Space Station Program Office, located at Reston, Virginia. Three project offices located at different NASA centers constituted the third tier of management. Each NASA center project office was in charge of a work package. The project offices and the project manager at each office were responsible for the delivery of the flight hardware or systems included in their work package, and for hiring a prime contractor to design, develop, and build those systems.

There were numerous prime contractors working on every aspect of the space station. The major contractors were: Grumman Aerospace Corporation, Boeing

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[25]McCurdy, *The Space Station Decision*, pg. 205.

Defense and Space Group, McDonnell Douglas Corporation, and Rocketdyne Division of Rockwell International. Grumman had the Level II prime contract, managed by the Space Station Program Office in Reston. They provided requirements definition and integration support. Boeing was the prime contractor for Work Package One, managed by the Marshall Space Flight Center. Work Package Two was managed by Johnson Space Center with McDonnell Douglas as the prime contractor. Lewis Research Center managed Work Package Four with Rocketdyne as the prime contractor.

The interfaces and divisions between the work packages were not very clean. Several of the work packages included distributed systems that would eventually be located throughout the space station. Work Package One contained the habitation, laboratory, and logistics modules, including life support systems. Work Package Two included the integrated truss assembly, mobile transporter, airlock, communications, data management, guidance, thermal control, solar array movement, propulsion, and ground-training systems. Work Package Three at the Kennedy Space Center was never awarded to a contractor; it included launch integration and preparation. Work Package Four encompassed the power system, including solar arrays, batteries, and the power distribution system.

Problems

The lines of reporting and communication in the SSF management structure were confusing and ineffectual. The project directors in the NASA centers reported to their Center Directors, not to the Space Station Program Office. The Center Directors were part of the management council of the space station, but were not in the direct line of management. In effect, the project managers were given directives by the Space Station Program Director, but were accountable to their Center Directors.

There was no easy and direct communication between the Center Directors and the project managers, located at their respective NASA centers, and the Space Station Program Manager in Reston, Virginia. The geographic disparity of these offices also led to a duplication of effort. The division of responsibility between the program office and the project offices was not always clear, resulting in several people in several different offices repeating the same tasks.

Changes in the design were also handled very inefficiently. Any changes made by a project office or one of their contractors was validated at the project office, and then sent to Reston to be validated by the program office. The turn-around time for these changes at the program office was sometimes in excess of a year. Once the change had been validated, it then had to pass from the program office back to the project office, then to the prime contractor, and then to the subcontractors. Often by the time the subcontractors were informed of a new design, it was already obsolete and replaced by another design.

The reasons why the management was set up in such a round-about manner have to do with the relationship between the NASA centers and NASA as an institution. Each NASA center has an independent history and sense of pride. The centers do not see themselves as under the authority of any other center, not even NASA headquarters. NASA headquarters is seen as another NASA center whose purpose is to interface with the government in order to secure the money that the other centers need to do their work. The NASA centers are very reluctant to give anyone in NASA outside of their own center any sort of control over the people or work inside the center. This management plan that relies on implied communication between the centers and the program office was designed to preserve the sovereignty of each center.[26] The work packages were designed so that no one center had a monopoly on

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[26]McCurdy, *The Space Station Decision*, pg. 208.

the space station work. When using these criteria, it is not surprising that the system was inefficient.

The SRT identified the following management problems with the SSF program:

(1) *Budget instability and the resultant redesign.* This problem was exacerbated by an overly optimistic cost estimate at the beginning of the program.

(2) *Senior management instability.* There were five different program managers during the first four years of the program.

(3) *Complicated interfaces and distributed integration.* Dividing the work among center work packages instead of deliverable launch packages led to complicated and unstable interfaces.

(4) *Excessive levels of management with unclear lines of authority.* The superfluous layers of management led to a large number of NASA and contractor employees working on program management issues instead of on the station.

Solutions

The management structure that the SRT recommended for the space station emphasized few layers of management and short, direct lines of communication. The team recommended a lead center approach, with a single prime contractor. The lead center would be a NASA center where the space station management and engineering team would work. They would all be located at that center and would report directly to the space station program management. The single prime contractor would control all aspects of the space station design, development, testing, and manufacturing. NASA's role would move to one of requirements definition and technical and safety oversight. The prime contractor would then hire subcontractors to fulfill various aspects of the space station planning and design.

The station work force would be divided into Integrated Product Teams (IPTs), and the Work Package division would be erased. The IPTs would each be in charge of a launch package, an entire set of hardware that will be launched together. This method of division allows for cleaner interfaces between working groups. The groups have to integrate their independent modules, but the problems of several design groups working on a single module would be eliminated.

The number of civil servants working on the space station would be cut drastically. There were approximately 2200 NASA employees working on SSF. This new management plan would cut that number to approximately 1000. Three hundred of these would be co-located at the lead center; the rest would provide support at the other NASA centers or with the contractors. The SRT estimated that 60% of all savings resulting from the redesign are a direct consequence of the simplification of the management structure.

Implications

The most important change in the management is the switch from a NASA program office to a prime contractor. This pushes NASA's role to one of overall requirements review and technical oversight. The prime contractor has responsibility for the space station program, including budgetary and schedule responsibility. Thus, NASA is removed from direct responsibility for any technical difficulties, or managerial difficulties, such as budget or schedule overruns. The redesign had several beneficial side-effects for NASA. They were able to present themselves as an organization eager to help the new administration, and concerned about cutting costs and streamlining operations. In addition, the redesign succeeded in protecting NASA from future problems by distancing the space station program accountability from NASA.

Russian Participation

Part of the charter of the Advisory Committee on the Space Station Redesign was to identify any areas where it might be possible to include Russian participation in the space station. Although the committee stated that cooperation with the Russians could "enhance the capability of the station, reduce cost, provide alternative access to the station, and increase research opportunities,"[27] the only concrete example of this was the recommendation to use the Russian Soyuz capsule as an Assured Crew Rescue Vehicle (ACRV). Despite this, the U.S. and Russia signed a compact in September, 1993, committing the two countries to cooperation in developing a space station.

The accord provided for two means of collaboration: adding Russian components to the space station design, and initiating an interim program of Mir 1/Shuttle utilization. Although the cost of the space station is to be shared among all international partners, the Mir 1/Shuttle program comes with a price tag. The U.S. agreed to pay Russia $100 million a year until 1997 for use of the Mir 1 space station. In return, the U.S. will be able to fly experiments on Mir 1, dock the shuttle to it, and possibly send astronauts for missions of up to six months. Although, on the surface, the price is for the use of Mir 1 facilities, there is no real need in the U.S. space program for these services. The U.S. is, in fact, subsidizing the Russian space program.

The Russian participation in the space station outlined in the accord is more extensive than that of any of the other international partners. Russia is already in the process of designing a Mir 2 space station. According to the rough plans of the joint committee, the main laboratory of Mir 2, along with its solar panels and a large power module, will be added to the basic international space station design. However, at the

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[27]"Space Station Alpha," NASA. September, 1993. pg. B.i.

time the accord was signed, the design with the added Russian modules had not undergone any technical scrutiny.

On the very day that the U.S. Senate voted on space station funding, the political situation in Russia became very grim. President Boris Yeltsin dissolved Parliament, which answered by declaring Vice President Alexander Rutskoi Acting President. Although some Senators felt that entering any long-term agreements with Russia was unwise given the unstable political environment, both President Clinton and Vice President Gore sent letters urging the Senate to support the agreement. Clinton called the space station "a symbol of peaceful international cooperation," and the space accord "the leading edge of the new relationship with Russia." Gore explained that "this initiative on space cooperation fits into the context of a much larger partnership with Russia, a relationship that will define the post-Cold War era." Sen. Tom Harkin (D-Iowa) was much more explicit. Although he was a long-time critic of the space station, he supported this accord, asking "Do we want the Russians, because of the dire economic circumstances, to start selling that technology to an unstable Third World country, like Saddam Hussein's and others?"[28]

However, the involvement of the Russians led to a debate similar to that discussed when deciding the extent of the involvement of the International Partners. Should the functionality of the space station depend on any Russian components, or should they simply enhance the capabilities of the basic station? "House space policy leaders wrote to Vice President Al Gore that Congress would insist that the United States 'maintain an independent capability to complete and operate the space station at all times.'"[29] Constrained by this injunction not to depend on Russian components, it seems unlikely that the Russian participation will reduce cost, as advertised by NASA.

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[28]Asker, James R. "Russian Role Key in Station Debate." *Aviation Week and Space Technology*. September 27, 1993. pg. 22.
[29]*ibid.*

It is interesting to note the change that has occurred in the attitude of the Clinton Administration toward the space station since the inception of the redesign. Initially, NASA was warned that if the redesigned space station did not meet the budget goal, it would be canceled. However, the station was not canceled, despite being well over the budget goal. Now that the Russian agreement has been added, it is not possible to have an optimal space station, either in terms of design or cost. However, the administration considers supporting the Russian space program monetarily and the Russian government psychologically as an important enough goal to justify the extra cost. For the first time since Apollo, the space program has become an element of US foreign policy.

Conclusions

By early 1993, the space station program had significant problems. The timing of the space station redesign was auspicious. The space station budget, along with the operational costs of the space shuttle, were eating up the NASA budget. The other missions of NASA such as space science and aeronautics were suffering from the huge budget demands of the high-profile projects. The goals of the redesign were good: decrease cost, decrease EVA time, deploy earlier, and plan for a shorter life span. The redesign initially appeared to achieve these goals to a certain extent. However, several months after the redesign, the new "Space Station Alpha" design had edged back toward the old Space Station Freedom design. This was because neither NASA, the administration, or the Congress were eager to give up any space station functionality. With the recent addition of the Russians to the program, the final design will most likely not closely resemble the work of the SRT.

Was the redesign necessary? Yes, it was. It was very important to curb the rampant spending in the space station program. The management changes that have occurred due to the redesign are possibly the single most important effect of the redesign. These changes have the potential to significantly decrease the cost of the station and the development time. NASA has lost much credibility in the past few years. The Challenger accident, the failure of the Hubble Space Telescope, the loss of the Mars Probe, and the cost and schedule overruns of the space station have all contributed to a public sense of disappointment with NASA. The redesign and subsequent management restructuring have the potential to change NASA's image for the better.

Was the redesign successful? This is a much more difficult question to answer. In certain aspects the redesign was very successful. The Clinton Administration was persuaded to continue support for the space station despite a very

tight budget. The schedule and cost overruns of the space station program needed to be stopped. It will take some time to determine if the redesign accomplished this, but if it did, the space station program will be much stronger for it. The issue of the technical success of the redesign is on the shakiest ground. Due partly to time constraints, the final redesigned space station is very similar to Space Station Freedom. However, the Russian participation in the partnership will change the design further, and make the SRT changes almost completely obsolete.

The addition of the Russians to the space station program is purely a political ploy. This is not necessarily a bad idea. The most successful NASA mission, Apollo, had a very political justification. Hopefully this will lead to increased support of the space station program. However, care must be taken to ensure the technical optimization of this new, hybrid space station. In effect, a new redesign is necessary to design the best joint space station. This will cost time and money, but it is vital to the future success of the space station. It will not be possible to make optimal use of the time and money spent to date; the addition of the Russians changes too many of the technical and operational aspects of the space station. At this point, NASA can only optimize the time and money spent in the future.

The biggest problem the space station has had in the past and still faces today is the problem of sufficient justification. The space science that can be accomplished on a manned space station is limited in scope. However, the importance of the space station lies in the demonstration of the technology. Can humans live and work in space? What is the effect of long-term exposure to weightlessness? Can mankind overcome all the obstacles to space exploration and escape the confines of the earth? Are we smart enough and brave enough to reach for the stars? To answer these questions is a sufficient reason to invest in a manned space program.

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